Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines

(Twelfth Annual Report)

Khizar Wasti, Ph.D.

Virginia Department of Health
Division of Health Hazards Control
1500 East Main Street
P.O. Box 2448
Richmond, Virginia 23218

In cooperation with

State Corporation Commission
1300 East Main Street
Richmond, Virginia 23219

March 20, 1997

An annual report submitted to the Virginia General Assembly, 1997 Session pursuant to Senate Joint Resolution No. 126 of the 1985 Session and Senate Joint Resolution No. 278 of the 1993 Session.

VDH VIRGINIA DEPARTMENT OF HEALTH
Protecting You and Your Environment

Acknowledgment

The Virginia Department of Health would like to thank Dean W. Broga, Ph.D., Director, Office of Environmental Health and Safety, Medical College of Virginia, Virginia Commonwealth University, Richmond, for reviewing this report.

Table of Contents

Page

Acknowledgment 1

Executive Summary 3

Introduction 6

Background 7

An Overview of Literature on the Health Effects of High Voltage Transmission Lines, 1995 - 1996 10

Energy Policy Act of 1992 17

Conclusion 20

References 21

Appendix A - Senate Joint Resolution No. 126 23

Appendix B - Senate Joint Resolution No. 278 24

Appendix C - Previous Reports in the Series 25

Executive Summary

Pursuant to Senate Joint Resolution No. 126 of the 1985 Session and Senate Joint Resolution No. 278 of the 1993 Session, this twelfth annual report on monitoring of ongoing research on the human health effects of high voltage transmission lines is submitted to the members of the 1997 Virginia General Assembly. Since the submission of the last report, entitled "Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Eleventh Annual Report)", dated February 26, 1996, several articles, reports, and reviews have become available in the literature on this subject. An overview of these publications is presented in this report.

There is a widespread notion among the public and the news media that exposure to power frequency electromagnetic fields (EMF) may be linked to adverse health effects in humans. The possible health effects of EMF exposure in an occupational environment were first reported in the literature from the former Union of Soviet Socialist Republics (USSR) in the mid-1960s. Several subjective complaints, involving the cardiovascular, digestive, and central nervous systems, were reported by electric switchyard workers. Subsequent studies of electric utility linemen in the United States failed to observe the same adverse health effects reported by their counterparts in the former USSR. Since that time, scientific interest has continued to increase in an attempt to ascertain an association between residential and occupational exposures to EMF and detrimental health effects.

Since 1979, a plethora of epidemiologic reports have appeared in the literature exploring a possible link between exposure to EMF and injurious human health effects. The most extensively studied health effects from exposure to EMF have been the occurrence of leukemia and brain tumors among residents near high voltage transmission lines and among workers occupationally exposed to EMF. While some epidemiologic studies have reported an association between exposure to EMF and an increased risk of certain types of cancer, others tend to evert such a relationship. The results of most studies which imply a link between exposure to EMF and an increased risk of cancer are only suggestive and are far from elucidating causation. The reported increases in cancer incidence with respect to cancer types or site are inconsistent and might be expected to occur on the basis of chance alone or as a result of some other, yet unidentified, causative factor. Many studies have relied on extrapolation of historical data to estimate past EMF exposure. In a very few studies where intensity of EMF was directly measured, the association between exposure and incidence of cancer appeared weaker in comparison with the association in those studies when the exposure was estimated based on extrapolation of historical data. Exposure to EMF is unavoidable due to ubiquitous sources other than high voltage transmission lines, such as wall wiring, lighting fixtures, distribution lines, substations, and from the use of a vast array of electrical appliances, such as televisions, clocks, computers, ovens, ranges, toasters, blenders, hair-dryers, irons, shavers, blankets, power tools, *etc*. Although used for short intervals, cumulative daily exposure to EMF from these devices may far exceed that from high voltage transmission lines.

Overall, the evidence for a causal link between exposure to power frequency EMF and increased incidence of cancer is weak, inconsistent, scientifically untenable, and lacks a clear dose-

response pattern. The relative risk inferred in some of the studies is low in magnitude and is within the range where experimental bias or confounding factors cannot be completely ruled out. While a causal association between EMF and cancer is not proven, the possibility of a small risk cannot be dismissed on the basis of currently available epidemiologic studies, since it is neither possible nor practical scientifically to prove a null hypothesis nor can any epidemiologic study rule out the possibility of a weak association. None of the laboratory studies in experimental animals has thus far augmented the epidemiologic studies in providing any persuasive evidence to establish a firm association between exposure to EMF and cancer.

Epidemiologic studies examining the possible association between EMF and cancer have some inherent strengths and weaknesses. In order to detect an association between a given risk factor and disease, an epidemiologic study must control for other potential risk factors that may be confounding this association. Even when all potential risk factors are known and controlled to the maximum extent possible, it is frequently impossible to rule out confounding when the strength of an association observed between the risk factor of interest and disease is weak. In reality, it is seldom possible to control for all other potential risk factors, because for many diseases, like various forms of cancer, those other risk factors are unknown. Some epidemiologic studies have found that exposure to EMF may confer a two- to three-fold increased risk of certain cancers. This is a fairly small increase when compared to the association between cigarette smoking and cancer, where the risk is increased by ten-fold or greater. Furthermore, exposure to EMF is universal and unavoidable. Thus, it is not possible to find a control group of individuals who would be unexposed; only populations with relatively greater or lesser exposure can be compared. Also, past exposure can only be estimated based on wiring configuration. There is no biological test to assess past exposure and current environmental measurements may be misleading. The assumption that the exposed group would have had a higher exposure to electromagnetic fields than the rest of the population may not be true and therefore, may skew the interpretation of the results of epidemiologic studies.

Although epidemiologic studies may fail to find an association between a given risk factor and disease, it is practically impossible for any epidemiologic study to rule out the possibility of a weak association. This is because the power of a study to confirm a negative association hinges on the prevalence of the disease of interest and the size of the study population. Because of the rarity of most tumors, any competent epidemiologic study that attempts to rule out very small associations between EMF and one type of cancer would have to include an exceedingly large population. Such a study would almost certainly be cost-prohibitive.

Scientific proof of a cause and effect relationship cannot be readily inferred from a single epidemiologic study. Causality is established using multiple criteria, only one of which is epidemiologic association. Other important factors in confirming a cause and effect relationship include strength of association, consistency and specificity of observations, appropriate temporal relationship, dose-response relationship, biological plausibility, and experimental verification. None of these factors by itself is sufficient to prove or disprove that an observed association represents a true cause and effect relationship. In the case of EMF, these tests for causality have not been satisfied for the implicit deleterious effects.

Laboratory experiments conducted on cells, tissues, and whole animals have shown that under certain conditions, exposure to EMF can produce changes in behavior and nervous system activity, and alterations in biological rhythms and the production of certain hormones. Biological changes such as these are not necessarily physiologically significant. Hence, it cannot be determined that these biological effects translate into adverse human health effects. The observed effects depend upon various factors, including field strength, frequency, duration of exposure, variability of exposure, rate of change in intensity, and interaction with the Earth's magnetic field. Unlike ionizing radiation, power frequency EMF do not appear to cause direct damage to DNA or other genetic material. Thus, it is believed that exposure to EMF could not, by itself, initiate cancer. However, some scientists have postulated that electric and/or magnetic fields may potentially serve as cancer promoters (an agent which facilitates the growth of a cancer which has already been initiated). These hypotheses are now being tested by researchers.

The Virginia Department of Health and the State Corporation Commission will continue to monitor the ongoing studies on the subject, and will inform the members of the General Assembly should evidence emerge establishing a clear link between adverse human health effects and EMF exposure.

Introduction

The Virginia General Assembly in its 1984 Session, pursuant to Senate Joint Resolution No. 26, resolved to establish a joint subcommittee to study the adequacy of the State Corporation Commission (SCC) oversight, the health and safety rules and regulations, and the statutes in the Code of Virginia in protecting the citizens of the Commonwealth when high voltage electrical transmission lines are constructed and maintained. The joint subcommittee held its first meeting on June 8, 1984, during which the Virginia Department of Health (VDH) was asked to review the human health effects of high voltage transmission lines. A report, "Health Effects of High Voltage Transmission Lines," dated August 15, 1984, was formally submitted to the members of the joint subcommittee during a meeting held on November 16, 1984.

Pursuant to Senate Joint Resolution No. 126 of the 1985 Session of the General Assembly (Appendix A), the SCC and VDH were requested to monitor the ongoing research on the health and safety effects of high voltage transmission lines. Further, the Department of Health, after consultation with the State Corporation Commission, was requested to report its findings annually to the General Assembly.

The 1993 Session of the General Assembly adopted Senate Joint Resolution No. 278 (Appendix B), requesting that the Department of Health and the State Corporation Commission continue to monitor relevant ongoing research as described in Senate Joint Resolution No. 126 of the 1985 Session and to submit annual reports thereon. Senate Joint Resolution No. 278 of the 1993 Session also requested that as part of the foregoing activity, the Department of Health and the State Corporation Commission monitor and, if feasible, participate in the study of electric and magnetic fields pursuant to the Federal Energy Policy Act of 1992.

This twelfth annual update of the 1984 report supplements information contained in the preceding reports. Previous reports in the series are listed in Appendix C. An overview of the literature that became available in 1995-1996 is presented in this report. Pursuant to Senate Joint Resolution No. 126 of the 1985 Session and Senate Joint Resolution No. 278 of the 1993 Session, this twelfth annual report on monitoring of ongoing research on the human health effects of high voltage transmission lines is submitted to the members of the 1997 Virginia General Assembly.

Background

Electric and magnetic fields, often referred to as electromagnetic fields (EMF), occur both naturally and as a result of generation, delivery, and use of electric power. In our society, where the use of electric power is pervasive, exposure to EMF is common from the vast array of electrical appliances and equipment, building wiring, distribution lines, and transmission lines.

EMF are fields of force and are created by electric voltage and current. They occur around electrical devices or whenever power lines are energized. Electric fields are due to voltage so they are present in electrical appliances and cords whenever the electric cord to an appliance is plugged into an outlet (even if the appliance is turned off). The strength of the electric field is typically measured in volts per meter (V/m) or in kilovolts per meter (kV/m). Electric fields are weakened by objects like trees, buildings, and vehicles. Burying power lines can eliminate human exposure to electric fields.

Magnetic fields result from the motion of the electric charge or current, such as when there is current flowing through a power line or when an appliance is plugged in and turned on. Appliances which are plugged in but not turned on do not produce magnetic fields. Magnetic fields are typically measured in tesla (T), or more commonly, in gauss (G) and milligauss (mG). One tesla equals 10,000 gauss and one gauss equals 1,000 milligauss. The strength of EMF decreases significantly with increasing distance from the source (1).

The Earth's natural electric field is essentially static (non-alternating) and is about 130 V/m. The Earth's magnetic field is also static and is about 0.5 G or 500 mG. In the United States, the electric power system uses alternating current (AC) that alternates back and forth (frequency) 60 times each second and is called 60-Hertz (60-Hz; cycles per second) power. In Europe and many other parts of the world, the frequency of electric power is 50-Hz.

There are basically three stages in generating electricity, or power, and moving the electricity from the electric stations to the end user. First, electricity is generated at an electrical generating station at about 20,000 volts or 20 kilovolts (kV). The power is then passed through a transformer which increases the voltage so that the power can be transported with minimum losses. In the second stage, electricity is transported over high voltage transmission lines ranging from 69 to 765 kV. Transmission lines connect to substations where the voltage is reduced and power is transferred to lower-voltage distribution lines. In the third stage, distribution lines deliver power locally to individual users. The distribution system is composed of two voltage levels. One is a "primary" circuit (2 to 59 kV) that delivers power from a substation to a distribution transformer. From there the power flows through a "secondary" circuit to an end user. The "secondary" circuit voltage is low enough (120 to 240 volts) to operate household electrical appliances, lights, etc. The amount of power that a line transmits is the product of its voltage and current. Power systems are designed to hold voltages relatively constant, while currents increase and decrease depending on the power demand. For a given voltage, the electric field remains relatively constant over time, but the magnetic field increases or decreases depending upon power demand (2).

The EMF from power lines and appliances are of extremely low frequency (ELF) and low energy. They are non-ionizing and are markedly different in frequency from ionizing radiations such as X-rays and gamma rays. As a comparison, transmission lines have a low frequency of 60-Hz while television transmitters have higher frequencies in the 55-890 million Hz (MHz) range. Microwaves have even higher frequencies, 1,000 MHz and above. Ionizing radiations such as X-rays and gamma rays have frequencies above 10^{15} Hz. The energy from higher-frequency fields is absorbed more readily by biological material. Microwaves can be absorbed by water in body tissues and cause heating which can be harmful, depending upon the degree of heating that occurs. X-rays have so much energy that they can ionize (form charged particles) and break up molecules of genetic material (DNA) and nongenetic material, leading to cell death or mutation. In contrast, extremely low frequency EMF do not have enough energy to heat body tissues or cause ionization (3).

Currently, in the United States there are more than 300,000 miles of AC power transmission lines ranging from 115 to 765 kV. In Virginia, the highest voltage on transmission lines is 765 kV. A typical home in the United States has a background magnetic field level (away from any appliances) that ranges from 0.5 mG to 4 mG, with an average level of 0.9 mG. Magnetic fields very close to most electrical appliances are often stronger than the fields directly beneath transmission lines. However, appliance fields decrease in strength with distance more quickly than do transmission line fields.

The strength of an electric field is proportional to the voltage of the source. Thus, the electric fields beneath high voltage transmission lines far exceed those below the lower voltage distribution lines. The magnetic field strength, by contrast, is proportional to the current in the lines, so that a low voltage distribution line with a high current load may produce a magnetic field that is as high as those produced by some high voltage transmission lines. In fact, electric distribution systems account for a far higher proportion of the population's exposure to magnetic fields than the larger and more obvious high voltage transmission lines (4).

Over the past three decades, both public controversy and scientific uncertainty have surrounded the subject of potential adverse human health effects from exposure to power frequency EMF. The first studies of possible health effects of EMF exposure in an occupational environment were reported from the former Union of Soviet Socialist Republics (USSR) in the mid-1960s. Several subjective complaints, involving the cardiovascular, digestive, and central nervous systems, were reported by electric switchyard workers. Subsequent studies of electric utility linemen in the United States failed to observe the same adverse health effects reported by their counterparts in the former USSR. Since that time, enormous strides have been taken to explore the nature of any association between residential and occupational exposures to EMF and deleterious health effects.

Recently, there has been a growing concern about the possible carcinogenic effects of EMF associated with such exposures. Since 1979, several epidemiologic studies have explored the association between exposure to EMF and increased risk of leukemia in children. Other epidemiologic studies have also examined increased incidence of leukemia and brain cancer among adults, especially with respect to occupational EMF exposure. In earlier studies there was an implicit

assumption that the relevant risk factor was exposure to electric fields. However, virtually all recent epidemiologic studies of cancer have focused on magnetic field exposures as the possible etiologic determinant.

An Overview of Literature on the Health Effects of High Voltage Transmission Lines, 1995 - 1996

Since the submission of the last report, entitled "Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Eleventh Annual Report)", dated February 26, 1996, several articles, reports, and reviews have become available in the literature on this subject. The following is an overview of the publications reviewed for this report. Conclusions from the various publications are either extracted verbatim or represent the views of the investigators and authors of the publications.

The American Cancer Society Staff's Review of EMF Epidemiologic Studies

Heath (5) reviewed the epidemiologic studies published to date concerning the occurrence of childhood and adult cancers under residential and occupational exposure conditions. The review's conclusions are as follows:

> "Evidence suggesting that exposure to EMF may or may not promote human carcinogenesis is mostly based on the epidemiologic observations reviewed. While those observations may suggest such a relationship for leukemia and brain cancer in particular, the findings are weak, inconsistent, and inconclusive."
>
> "Where published studies show increased values of risk, those increases are not great, the larger increases tending to arise from small numbers with relatively wide statistical confidence intervals. Those occasional risk patterns that suggest rising risk with rising levels of exposure (biologic gradient or dose-response) are inconsistent and not often repeated in different studies. Increases in risk at specific cancer sites are likewise inconsistent. While some studies suggest increased risk for both leukemia and brain cancer, others do so for leukemia but not brain cancer and vice versa. Where breast cancer has been studied, results also vary. Such inconsistencies persist even when one limits attention to larger, stronger studies (discounting the initial investigations that serve principally to raise hypotheses for later inquiry)."
>
> "The weakness and inconsistent nature of epidemiologic data, combined with the continued dearth of coherent and reproducible findings from experimental laboratory research, leave one uncertain and rather doubtful that any real biologic link exists between EMF exposure and carcinogenicity."

A Mini-review of EMF Carcinogenesis

Moulder and Foster (4) reviewed over 100 published epidemiologic and laboratory studies relevant to addressing the possibility that power frequency EMF are carcinogenic. The review concluded:

> "Review of the epidemiologic evidence shows that the association between exposure to power-frequency fields and cancer is weak, and inconsistent, and generally fails to show a dose-response relationship. The laboratory studies of power-frequency fields show little evidence of the type of effects on cells or animals that point towards power-frequency fields causing or contributing to cancer. Finally, from what is known about the biophysics of power-frequency fields, there is no reason to even suspect that they would cause or contribute to cancer. Application of "Hill's criteria" to epidemiologic and laboratory studies shows that the evidence for a causal association between exposure to power-frequency fields and the incidence of cancer is weak."

A Review of Epidemiologic Studies Relevant to EMF and Childhood Leukemia

Levallois (6) evaluated the epidemiologic studies relevant to the potential role of power frequency magnetic fields as a causal factor for acute childhood leukemia. The conclusions of the review are as follows:

> "On the bases of epidemiologic findings to date, as well as on the analysis of their strengths and limitations and on the discussion of classical criteria for causal inference, it appears that the 50 Hz to 60 Hz magnetic fields emanating from electrical wiring cannot be dismissed as a possible causal factor for childhood leukemia. The evidence is even stronger when the results of recent epidemiologic studies are taken into account. The alternative explanation of a confounder effect for the epidemiologic findings seems less plausible but has not been completely ruled out. One of the weakest arguments for causal inference is the lack of currently understood biological plausibility. Some authors have argued that the EMF effect in promoting cancer is conceivable but not very plausible. It is not possible currently to address this question unequivocally; although some authors have proposed plausible mechanisms, much remains to be discovered.
>
> The public health impact of possible effects of exposure to EMF is difficult to assess. Lack of data on the definition of an effective dose, the size of the population exposed, and a clear dose-response relationship preclude a precise estimate of impact. Nevertheless, given the large number of children exposed to EMF, such an impact could be significant. Therefore, it might be prudent to look for interim preventive measures while we await results of further epidemiologic or experimental research."

Magnetic Fields and Cancer Literature Review

Carstensen (7) reviewed more than 100 studies published in the literature and concluded as follows:

"The massive body of epidemiological data searching for a relationship between magnetic field exposure and the incidence and development of cancer tells us that the presumably exposed population has essentially the same health characteristics as the population as a whole. Some comfort may be found in the fact that epidemiology has not revealed any large or unusual associations. But, the cost to society for this work has been substantial, and it would be difficult to justify further use of epidemiology in the study of magnetic field bioeffects.

These predominantly negative results are not particularly reassuring, however. It simply underscores the obvious fact that epidemiology does not have the power to detect subtle effects, particularly when study groups with clearly different exposure levels cannot be identified, as is the case for magnetic fields. In fact, if there really were effects, the risk ratios would be understated because of the overlaps in true 'exposures' in the arbitrarily chosen populations used in the studies.

Laboratory studies should provide the sensitivity that is lacking in epidemiology. In addition, laboratory animals can be (and have been) exposed to huge fields for long periods of time. Certainly, some of the suggested positive effects should be followed up, but overall, results from studies of laboratory animals give little encouragement for the hypothesis that magnetic fields affect the development of cancer."

Swedish Review of EMF Epidemiological and Experimental Findings

Hardell et al. (8) published an extensive review of more than 300 epidemiological and experimental studies published in the scientific literature between 1979 and 1994. The objective of the review was to evaluate the possible carcinogenicity of low frequency EMF and to evaluate the scientific basis for occupational and/or environmental standard setting. The review concluded that there are possible associations between i) an increased risk of leukemia in children and the existence of, or distance to, power lines in the vicinity of their residence, ii) an increased risk of chronic lymphatic leukemia and occupational exposure to low frequency EMF, and iii) an increased risk of breast cancer, malignant melanoma of the skin, nervous system tumors, non-Hodgkin lymphoma, acute lymphatic leukemia or acute myeloid leukemia and certain occupations. Possible association in the review was characterized based on three or more studies showing a pattern of an association with measured, estimated, or evaluated EMF exposure or exposure hygienic classification. However, the review noted the lack of a dose-response or a causal relationship. With regard to scientific basis for occupational and/or environmental standard setting, the review concluded:

"The scientific basis underlying the setting of environmental and occupational standards include, *inter alia*, the establishment of a dose-response relationship and thus an assessment of a causal relationship between agent, exposure characteristic and risk as observed in epidemiological and/or animal studies. In the epidemiological and

experimental studies of the EMF literature the dose is far from well-defined. Further studies are needed to resolve this issue.

Furthermore, for extrapolation purposes it would ideally be possible to calculate the risk at exposure levels outside the observation range. This includes the use of a biologically relevant model. It is not generally possible to extrapolate without at least an indication of a plausible biological mechanism responsible for the observed effects. This mechanism should be reasonably argued to be valid also for humans. Such information is presently lacking in the area of EMF research.

With these uncertainties in mind, our conclusion is that there is no scientific basis at present for setting environmental or occupational standards."

Los Angeles Study of Childhood Brain Tumors

A case-control study (9) examined potential association between exposure to residential magnetic fields and childhood brain tumors in Los Angeles County, California. The study included 298 children under age 20 years diagnosed with a primary tumor of the brain, cranial nerves, or cranial meninges between 1984 and 1991. The control group consisted of 298 children with the same range of birth years and the same distribution by sex as the cases, and was selected by random digit dialing. The residential magnetic field level was determined for Los Angeles County homes in which the cases and controls had lived from conception to diagnosis (1,131 homes) by mapping and coding the wiring configurations outside the home and by exterior spot and profile measurements. In addition, for a subset of subjects (211 homes), 24-hour measurements were taken in the child's room and in one other room. Overall, the results of the study did not show an increase in risk of developing a childhood brain tumor with increasing exposure to magnetic fields, as assessed by 24-hour measurements, spot measurements, high wiring configurations, or with any of several other potential sources of exposure, such as use of various electrical appliances. However, when analyses were restricted to very high exposures (defined as above 3 mG) inside the home, slightly elevated risk was observed. The risk was not statistically significant and the number of subjects living in homes with very high interior fields was too small to show an effect clearly.

Seattle Study of Childhood Brain Tumors

Gurney et al. (10) conducted a population-based case-control study of childhood brain tumor incidence in the Seattle, Washington area. The primary purpose of the study was to evaluate the possible association between high-current residential power line configurations and brain tumor occurrence in children. The study was comprised of 133 children under age 20 years who were diagnosed with a primary tumor of the brain in western Washington state during 1984 and 1990. The control group consisted of 270 children and was selected by random digit dialing. The study did not find high-current power lines at the homes of children to be associated with increased risk of brain tumor. There was no evidence for a dose-response relation with increasing power line configuration levels. Electric heating sources were not associated with brain tumor occurrence, nor

was use of electric blankets or heated water beds. Also, there was no evidence that appliances used intermittently for short periods of time, such as hair dryers, curling irons, or microwave ovens, were associated with brain tumor occurrence. According to the authors of the study, "These data do not support the hypothesis that exposure to magnetic fields from high-current power lines, electric heating sources, or electric appliances is associated with the subsequent occurrence of brain tumors in children."

Birth Defects Study in France

A case-control study (11) was conducted in France to determine whether living closer to high voltage power lines increased the risk of congenital anomalies. The cases consisted of all children with congenital anomalies during the first year of life, identified to the population-based registry in Central-East France between 1988 and 1991. Each case was matched to two controls by year of birth and community. The study was comprised of 151 cases and 302 controls. For every case and control, the distance from the high voltage power line to the maternal residence at the time of birth of a child was measured as a surrogate for EMF exposure. No spot measurements of EMF were made. The study did not reveal a relationship between residential proximity to a high voltage power line and overall risk of congenital anomalies, nor was there any specific type of malformation among infants born within 300 feet of a high voltage power line. Among the eleven cases within 300 feet of high voltage power lines, there were two children with chromosomal anomalies. The study did not have enough statistical power to determine whether the prevalence of a specific congenital anomaly is significantly increased as a result of living near a high voltage power line.

Exposure to EMF and Fetal Growth Retardation

Bracken et al. (12) conducted a prospective study of pregnant women to evaluate the relation of birth weight and fetal growth retardation with use of electrically heated water beds and electric blankets during pregnancy. A total of 2,967 women receiving their prenatal care at 11 private obstetrical practices and two health maintenance organizations in the New Haven, Connecticut, area comprised the study population. Exposure to EMF was assessed using personal monitors, spot measurements of the fields in homes, video display terminal use, and wiring configuration codes. The study used a "nested" design in which population subsets were placed in different monitoring protocols. Exposure to EMF during pregnancy, either at conception, at ≤16 weeks, or in the third trimester, showed no important relation to risk of low birth weight or fetal growth retardation. The result was the same whether the fields were measured directly or estimated. None of the exposure measures showed a dose-response relationship to risk.

Occupational Exposure to EMF and Suicide

A case cohort study (13) was conducted to investigate the association between suicide and occupational exposure to electric fields, magnetic fields, and pulsed electromagnetic fields. The study population consisted of 21,744 male electrical utility workers who were employed at Hydro Québec, Canada. Subjects included in the study were employed between 1970 and 1988 and had worked at

least one continuous year. A subcohort of 215 subjects was selected as a 1% random sample of the entire cohort. Cumulative and current exposures to electric fields, magnetic fields, and pulsed electromagnetic fields were estimated through a job exposure matrix. For cumulative exposure, three groups were defined (low, medium, and high). For current exposure indices only two groups were defined (low and medium). Forty-nine deaths from suicide were identified in the study period. Risk ratios were calculated using the arithmetic mean as well as the geometric mean of field strength. The study found some evidence for an association between suicide and cumulative exposure to the geometric means of electric fields for the medium exposure group only, but there was no evidence for dose-response. No association was found with exposure to magnetic fields or pulsed electromagnetic fields. For current exposure, there was a slightly increased risk of suicide with pulsed electromagnetic fields in the high exposure group. There was no association with cumulative exposure for arithmetic means of electric fields and with current exposure for geometric means of electric fields. Thus, the evidence from this study for a causal association between exposure to electric fields and suicide is weak. The small number of deaths from suicide and inability to control for all potential confounding factors were the main limitations of this study.

The authors of this study also analyzed the data for overall mortality among the same study population in another report (14). Of all 21,744 subjects in the cohort, 1,582 had died by the end of the follow up period. The mean length of follow up was 12.9 years. The mean age at the time of hiring was 26.2 years and the mean age at death or end of follow up was 46.1 years. Analysis of mortality data provided no evidence of increased mortality overall. Death rates including mortality from all cancers were substantially below those of the Québec male population. The lower death rates probably resulted from a healthy worker effect, as the workers were all fit enough to work during the study period.

Energy Policy Act of 1992

A federally coordinated EMF Research and Public Information Dissemination (RAPID) Program was established by the Energy Policy Act of 1992. Section 2118 of the Act directs the U.S. Department of Energy (DOE) to establish a comprehensive program to:

- determine whether or not exposure to electric and magnetic fields produced by generation, transmission, and use of electric energy affects human health;
- carry out research, development, and demonstration with respect to technologies to mitigate any adverse human health effects; and
- provide for dissemination of information on possible human health effects, the types and extent of human exposure to EMF, technologies to measure and characterize fields, and methods to assess and manage EMF exposure.

DOE is responsible for the overall administration of the 5-year, $65 million EMF RAPID Program and directs research on exposure assessment and field management techniques. The National Institute of Environmental Health Sciences (NIEHS) directs the risk assessment and health effects research. The public information component of the program is the responsibility of both DOE and NIEHS. The program is jointly funded by both Federal and non-Federal sources. Non-Federal source contributions account for at least 50% of the total funding (15).

The first funded year of the RAPID Program was fiscal year 1994. Federal appropriations of $3.9 million were fully matched by industry to yield a total budget of $7.8 million. In fiscal year 1995, Federal appropriations for the program were $7.7 million. Non-Federal contributions of $6.0 million were received making the total budget for 1995 $13.7 million. Current non-Federal contributions, or commitments to contribute to the RAPID Program, total $23.6 million. An additional $8.9 million will be necessary to fully match the $32.5 million in Federal funds authorized. Multi-year health effects research projects and related EMF measurement and exposure assessment projects are now underway through grants funded in fiscal years 1994 and 1995 (16).

The Act also establishes two committees and their responsibilities to ensure broad representation of expertise and interest in the EMF issue. An Interagency Committee representing nine Federal agencies is responsible for the following: developing the program agenda; establishing guidelines for interagency coordination; and monitoring, evaluating, and reporting program results. The Interagency Committee includes:

- Department of Energy
- National Institute of Environmental Health Sciences
- Environmental Protection Agency
- Department of Defense
- Occupational Safety and Health Administration (Department of Labor)

- National Institute of Standards and Technology (Department of Commerce)
- Department of Transportation
- Rural Electrification Administration (Department of Agriculture)
- Federal Energy Regulatory Commission

The Interagency Committee, established by the President of the United States, must also prepare two reports to the Congress: an interim report in 1995 and a final report in 1997.

The RAPID Program also receives guidance from the National EMF Advisory Committee (NEMFAC), whose members are drawn from representative constituencies including public interest groups, organized labor, state governments, academia, and industry. The Advisory Committee also provides recommendations to the Interagency Committee on several tasks. The National Academy of Sciences will review and evaluate the research conducted under the EMF RAPID Program (15).

The RAPID Program has the central goal of determining if electric and magnetic fields associated with the generation, transmission, and use of electrical energy pose a risk to human health. The fact that twenty years of research have not answered that question is clear evidence that health effects of EMF are not obvious and that risk relationships, if risk is identified, are not simple. Because epidemiologic studies have raised concerns regarding the connection between certain serious human health effects and exposure to electromagnetic fields, the program adopts the hypothesis that exposure to electric or magnetic fields under some conditions may lead to unacceptable risk to human health. The focus of the program is not only to test, as far as possible within the statutory time limits, that hypothesis for those serious health effects already identified, but to identify as far as possible the special conditions that lead to elevated risk and to recommend measures to manage risk. The RAPID Program complements other Federal and non-Federal EMF research, and the results of these other programs will be considered in light of the new data obtained from the RAPID Program.

An important feature of the RAPID Program that distinguishes it from previous programs is its focus on a risk assessment framework for decision making. This includes the specific task of developing a detailed risk assessment model for potential human health effects of electric and magnetic fields, as well as adopting an overall risk assessment approach for all activities funded. The risk assessment approach during the early phases of the program will be useful in reviewing the evidence of existing research to determine gaps and areas where resources should be focused. In the later phases of the program, risk assessment research will form the basis for decision-makers' interpretation of the health effects research and suggest directions for assessing the nature and extent of any risk. Further, risk assessment research is expected to assist program managers with systematic identification of key issues related to potential health effects. Consequently, it will be an invaluable tool in directing the communication component of the program (15).

The risk assessment framework is an important cornerstone of the entire RAPID research program. The framework provides a context for making funding decisions and should not be confused with the formal risk assessment model, which will be independently developed for the program. Since research funded under the RAPID Program must be oriented toward testing the overall hypothesis, some methodology must be employed to ensure that all research incrementally

addresses the hypothesis in the context of the specific human endpoints selected. Thus, the hazard identification process must be employed to determine what additional information is needed to test the hypothesis. This approach will ensure that all research is policy focused. Specific steps for implementing the risk assessment framework will be developed by NIEHS.

Essential to the RAPID Program strategy is a continual application of the risk assessment approach. Evaluation of research conducted through the program, and independent of the program, will be ongoing and will be used to refine program activities by redirecting, expanding or concentrating the areas of research. Such refinements should result in narrowing the focus to those health effects and areas of research that will maximize the chance of being able to answer the statutory questions within the program time frame (15).

Conclusion

The epidemiologic studies published in the scientific literature during 1995-1996 have not contributed any significant new information to the existing state of knowledge in explicitly determining the specific nature and magnitude of the potential adverse effects on human health attributable to EMF exposure from high voltage transmission lines. Since 1979, more than one hundred epidemiologic reports have appeared in the literature exploring a possible link between exposure to EMF and injurious human health effects. The most extensively studied health effects from exposure to EMF have been the occurrence of leukemia and brain tumors among residents near high voltage transmission lines and among workers occupationally exposed to EMF. While some epidemiologic studies have reported an association between exposure to EMF and an increased risk of certain types of cancer, others tend to evert such a relationship. The results of most studies which imply a link between exposure to EMF and an increased risk of cancer are only suggestive and are far from elucidating causation. The reported increases in cancer incidence with respect to cancer type or site are inconsistent and might be expected to occur on the basis of chance alone or as a result of some other, yet unidentified, causative factor.

Based on the available literature to date, the overall evidence for a causal link between exposure to power frequency EMF and increased incidence of cancer appears to be frail, contradictory and inconsistent, and lacks a clear dose-response pattern. The relative risk inferred in some of the studies is fairly small and is within the range where experimental bias or confounding factors cannot be completely ruled out. While a causal association between EMF and cancer is not proven, the possibility of a small risk cannot be dismissed since it is neither possible nor practical scientifically to prove a null hypothesis nor can any epidemiologic study rule out the possibility of a weak association. None of the laboratory studies in experimental animals has thus far augmented the epidemiologic studies in providing any persuasive evidence to establish a firm association between exposure to EMF and cancer.

References

1. Information Ventures, Inc. Status report on potential human health effects associated with power frequency electric and magnetic fields. Reporting Period: June 1993 - June 1994. Prepared for the Maryland Department of Natural Resources and Public Service Commission of Maryland, January 1994.

2. Electro-Magnetic Health Effects Committee, Public Utility Commission of Texas. Health effects of exposure to powerline-frequency electric and magnetic fields. A report prepared for the Public Utility Commission of Texas, March 1992.

3. Bonneville Power Administration. Electrical and biological effects of transmission lines: A review. U.S. Department of Energy, Portland, Oregon, 1993.

4. Moulder JE, Foster KR. Biological effects of power-frequency fields as they relate to carcinogenesis - Minireview. Proc Soc Exp Biol Med 1995;209:309-324.

5. Health CW. Electromagnetic field exposure and cancer. A review of epidemiologic evidence. CA Cancer J Clin 1996;46:29-44.

6. Levallois P. Do power frequency magnetic fields cause leukemia in children? Am J Prev Med 1995;11:263-270.

7. Carstensen EL. Magnetic fields and cancer. IEEE Engineering in Medicine and Biology 1995;14:362-369.

8. Hardell L, Holmberg B, Malker H, Paulsson L-E. Exposure to extremely low frequency electromagnetic fields and the risk of malignant diseases - An evaluation of epidemiological and experimental findings. Eur J Cancer Prev 1995;4(Supplement 1):3-107.

9. Preston-Matrin S, Navidi W, Thomas D, Lee P-J, Bowman J, Pogoda J. Los Angeles study of residential magnetic fields and childhood brain tumors. Am J Epidemiol 1996;143:105-119.

10. Gurney JG, Mueller BA, Davis S, Schwartz SM, Stevens RG, Kopecky KJ. Childhood brain tumor occurrence in relation to residential power line configurations, electric heating sources, and electric appliance use. Am J Epidemiol 1996;143:120-128.

11. Robert E, Harris JA, Robert O, Selvin S. Case-control study on maternal residential proximity to high voltage power lines and congenital anomalies in France. Pediatr and Perinat Epidemiol 1996;10:32-38.

12. Bracken MB, Belanger K, Hellenbrand K, Dlugosz L, Holford TR, McSharry J-E, Addesso K, Leaderer B. Exposure to electromagnetic fields during pregnancy with emphasis on electrically heated beds: Association with birthweight and intrauterine growth retardation. Epidemiology 1995; 6:263-270.

13. Baris D, Armstrong BG, Deadman J, Thériault G. A case cohort study of suicide in relation to exposure to electric and magnetic fields among electrical utility workers. Occup Environ Med 1996;53:17-24.

14. Baris D, Armstrong BG, Deadman J, Thériault G. A mortality study of electrical utility workers in Québec. Occup Environ Med 1996;53:25-31.

15. EMF RAPID Program Interagency Committee. Research agenda and communication plan - EMF RAPID Program. U.S. Department of Energy Report No. DOE/EE-0021, May 1994.

16. The EMF Interagency Committee. Progress report on the electric and magnetic fields research and public information dissemination program. U.S. Department of Energy Report No. DOE/EE-0088, December 1995.

Appendix A

Senate Joint Resolution No. 126

Requesting the State Corporation Commission and the Department of Health to monitor ongoing research on the health and safety effects of high voltage transmission lines.

Agreed to by the Senate, January 30, 1985
Agreed to by the House of Delegates, February 14, 1985

WHEREAS, in recent years there has been a significant increase in the concern over the health and safety aspects of high voltage transmission lines; and

WHEREAS, a joint subcommittee established pursuant to Senate Joint Resolution No. 26 of the 1984 Session of the General Assembly carefully studied the health and safety aspects and heard from a number of experts who were not in agreement over whether harmful effects exist; and

WHEREAS, currently there are a large number of studies on the health and safety of such lines, the result of which the joint subcommittee feels should be continuously monitored so that if any causal relationships develop the General Assembly will be informed and will be able to take appropriate action to protect the citizens of Virginia; and

WHEREAS, it is the sense of the joint subcommittee that this monitoring could best be done by the State Corporation Commission, which by statute has oversight over the construction of transmission lines, and the Department of Health; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the State Corporation Commission and the Department of Health are requested to monitor the ongoing research on the health and safety effects of high voltage transmission lines; and, be it

RESOLVED FURTHER, That the Department of Health, after consultation with the State Corporation Commission, is requested to report its findings annually to the General Assembly.

Appendix B

Senate Joint Resolution No. 278

Requesting the State Corporation Commission and the Department of Health to include studies pursuant to the Energy Policy Act of 1992 in their monitoring of research to determine whether electric and magnetic fields affect human health.

Agreed to by the Senate, February 9, 1993
Agreed to by the House of Delegates, February 17, 1993

WHEREAS, Senate Joint Resolution No. 126 (1985) requested the State Corporation Commission (SCC) and the Department of Health (DOH) to monitor ongoing health and safety research relating to high-voltage electric transmission lines and requested DOH, after consultation with the SCC, to report its findings annually to the General Assembly; and

WHEREAS, the General Assembly has received six such annual reports reviewing the extensive research related to the subject; and

WHEREAS, public interest in this subject has continued; and

WHEREAS, the Federal Energy Policy Act of 1992 requires the Secretary of Energy to undertake a comprehensive five-year study to determine whether electric and magnetic fields produced by the generation, transmission and use of electric energy affect human health and authorizes an appropriation of $65 million, to be supplemented by nonfederal sources, for that purpose during the years 1993-1997 so that action, if any, to be taken by the federal government can be based upon scientifically valid research; and

WHEREAS, the Department of Energy, the National Institute of Environmental Health Sciences, the Environmental Protection Agency, the Department of Defense, the Occupational Safety and Health Administration, the National Institute of Standards and Technology, the Department of Transportation, the Rural Electrification Administration and the Federal Energy Regulatory Commission will participate in the study, and the National Academy of Sciences will periodically evaluate the progress of the study; and

WHEREAS, that Act provides for the establishment of the National Electric and Magnetic Fields Advisory Committee to advise the Secretary of Energy with respect to the design and implementation of the study; the committee shall be composed of ten members including representatives of state health agencies and state regulatory agencies as well as other experts in the field; and

WHEREAS, the results of the study, as well as information compiled during the course of the study, may be useful to the General Assembly; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the SCC and DOH, with assistance from the Medical College of Virginia, be requested to continue to monitor relevant on-going research as described in SJR 126 and to submit annual reports thereon; and, be it

RESOLVED FURTHER, That as part of the foregoing activity, the SCC and DOH be requested to monitor and, if feasible, participate in the study of electric and magnetic fields pursuant to the Energy Policy Act of 1992.

Appendix C

Previous Reports in the Series

1. Health Effects of High Voltage Transmission Lines, August 15, 1984.

2. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines, September 25, 1985.

3. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Second Annual Report), November 13, 1986.

4. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Third Annual Report), October 23, 1987.

5. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Fourth Annual Report), December 5, 1988.

6. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Fifth Annual Report), March 15, 1990.

7. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Sixth Annual Report), January 10, 1991.

8. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Seventh Annual Report), March 10, 1992.

9. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Eighth Annual Report), March 24, 1993.

10. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Ninth Annual Report), April 20, 1994.

11. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Tenth Annual Report), March 14, 1995.

12. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Eleventh Annual Report), February 26, 1996.